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Present state of wind energy utilisation in Hungary: policy, wind climate, and modelling studies

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Abstract

Earlier renewable energy studies suggested that Hungary does not have considerable extractable wind power due to the low mean annual wind speed. Recent technological developments with the remarkable increase of tower height and rotor diameter of wind power stations made it possible to reevaluate wind energy consumption in continental regions such as the Carpathian Basin. This paper presents the policy changes of the Hungarian government concerning the joining of the country to the European Union planned in 2004. In order to support governmental efforts on renewable energy consumption a research project started on mapping potential wind resources of the country. It was essential to measure and analyse the flows in the lower 100–150 m of the boundary layer through vertical profile estimations. Then, serving the optimal siting the WAsP model has been applied to extrapolate the measured data at different regions of Hungary.

Contents

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1. National plans and governmental efforts

In the last few decades a significant growth in the consumption of renewable energy sources could be observed world-wide. Due to decreasive reserves and rising costs of fossil fuels, this tendency is intensifying recently. Policy makers of the European Community set as a goal to double the share of renewable energy carriers in energy consumption from around 6% (level 1997) to 12% for the year 2010 [1]. Hungary are going to join the European Union in 2004 according to optimistic estimations. Therefore, special efforts are declared by the Hungarian government to facilitate the use of renewable energy resources. In order to increase the share of renewable energy two ministerial orders came into force in 1999 [2,3].

1. The Parliament voted the 2199/1999.(VIII.6.) decree named “Energy Business Model” that determines energy development, which has to be reached before the Hungarian EU membership. The main targets of this model involve the concepts of energy savings, increasing energy efficiency, expansion of renewable energy consumption and environmental protection.
2. Associated to the Business Model an Acting Plan was worked out and voted under 1107/1999.(X.8.) governmental decree. In its 15 sections, besides the new structure of the privatised and reorganised energy sector, the financial regulations are described. One focus point of this plan is to propagate and facilitate the renewable energy consumption, through partly financed tenders [2].

The main concepts of these decrees realised (from 2001) in the frame of the National Research Development Program called the Széchenyi Plan, in which several innovative economic and business enhancement projects took place. The governmental budget estimates of this program was 2.5 billions EUR for the 2001–2002 period. Thirty three percent of the budget is reserved for the energy sector that is available through open ministerial tenders. In 2001 more than 200 applications arrived and most of them got accepted. A great portion of the accepted tenders are connected to research, development, and the application of renewable energy resources, or installation of energy conversion systems.

Hungary’s traditional coal-dominated energy structure is changing slowly. In 2000, renewable energy represented approximately 3.6% of the total primary energy consumption only. The major source is the firewood with 72% of the total renewable energy consumption, geothermal energy, biomass burning, and hydropower gives 11, 11, and 3%, respectively. The rest contains biogas and communal waste burning,

and solar power. Since the first wind power stations of Hungary (Várpalota—250 kW and Kulcs—650 kW) have just been installed last year, wind energy does not appear in these statistics.

In order to fulfil the expectations of the European Union, Hungary would like to double the share of the renewable energy resources (to reach 7.2%) in the total primery energy consumption until 2010. Biomass is expected to become a major alternative for coal-power generation in our country.

Among renewable energy resources wind energy is the fastest-growing, with an average increase rate of 30% annually over the past five years [4]. Unfortunately, Hungary is not one of the countries whose wind climate can be characterised by high wind speed values. However, because of the shortage in traditional fuel resources, the rising energy costs, and the unbalanced export-import ratio of energy supply it became necessary to consider and review the consumption of our potential wind energy resources. This was the main purpose of our research project started in 1995.

2. Potential wind resources of Hungary

The aim of our investigations was to study and map the wind climate and review the potential wind energy use of Hungary. Optimal siting of wind power stations requires knowledge of detailed topography and wind climate of the studied region. Since climate change can be an important factor as well, the wind climate variations of Hungary have been analysed for the last century. Wind climatological data from all available sources have been collected. Based on the viewpoint of wind energy utilisation the proper climate indicators would be the wind climate tables [5,6]. However, measurements serving climatological diagrams are not available from the earlier decades of the last century. Therefore, spatial distribution of daily, monthly, and annual mean wind speed was analysed summarising all available information. Difficulties arose in the comparison because the various sources applied different averaging periods and various measuring networks [7].

The planned wind energy utilisation requires not just historical but recent wind climate information, as well. Figure 1 demonstrates the wind field of Hungary using hourly wind speed averages of five-year-long data base (1997–2001) of 29 climate stations. Because of the different heights of measuring instruments, wind data were converted to standard measuring height (10 m) using the logarithmic wind profile equation. Based on earlier [7] and recent wind climate studies of Hungary it can be concluded that maximum wind speed values occur near the north-western part of the country (around the Dévényi-gate). In general, two minimum wind speed centers appear on the maps, one in the south-western and the other in the north, north-eastern part of Hungary. Mean values in Trans-Danubia are higher than in the eastern part of the country. Although maximum and minimum centers do not show seasonal replacements, values are higher, and the range between the maximum and minimum values is also getting somewhat higher in spring than in autumn. Based on the analysed wind speed data no significant changes can be observed during the 20th century, nevertheless for selected areas and shorter periods significant trend was found

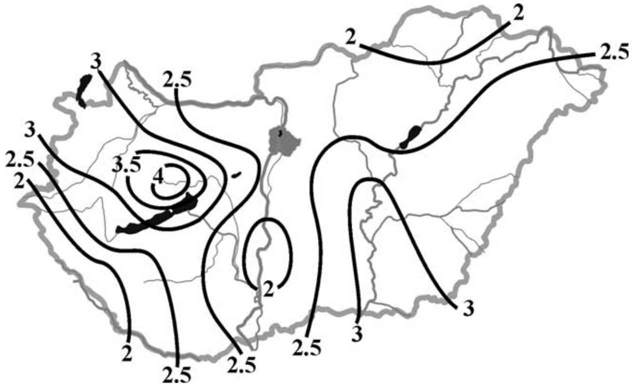


Fig. 1. Spatial distribution of mean wind speed (m s^{-1}) over Hungary.

[8]. Because of the inhomogeneity of time series, the changes in measuring techniques and instruments, the several replacements of measuring stations, and their changing surroundings, this summary obviously includes some uncertainties. Despite all these factors it is very unlikely that a significant trend would stay hidden in this analysis.

In Hungary wind energy utilisation is generally the most critical in transitional seasons where annual maximum and minimum values occur. However, some stations show different characteristics. Using the annually averaged wind speed data of the last five years (1997–2001), the maximum value (4.08 m s^{-1}) appeared in station Szentkirályszabadja (47.07°N, 17.83°E) and the minimum (1.47 m s^{-1}) was found in Jósvafö (48.48°N, 20.53°E). In Figs. 2 and 3 the annual and the daily cycles of wind speed are shown for these stations demonstrating the quartile values of the time series. In both cases the daily maximum wind speed values occur around midday. At station Jósvafö the annual course is smoothed due to the sheltered valley effect of the station. The minimum was found in December, and the maximum in April.

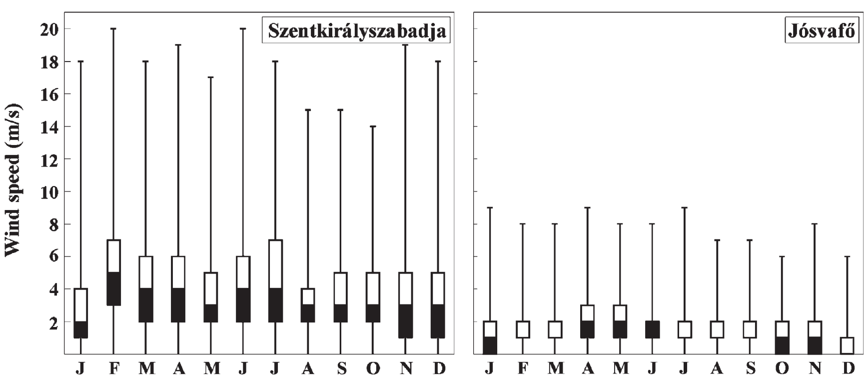


Fig. 2. Schematic plot of annual cycle of wind speed at Szentkirályszabadja and Jósvafő.

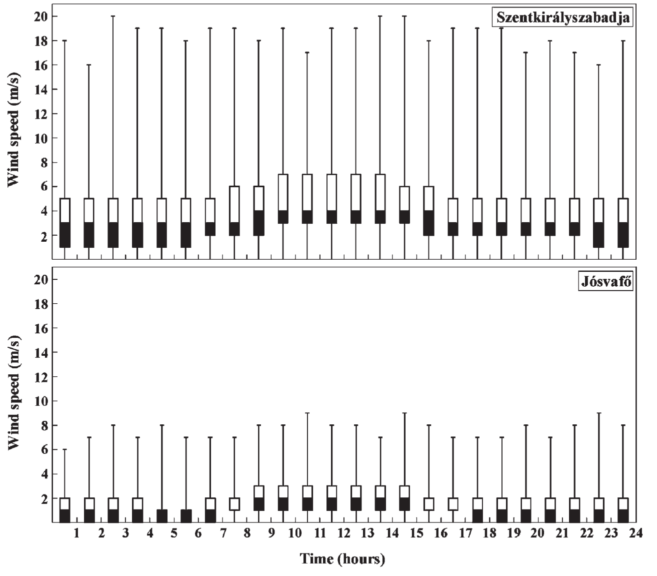


Fig. 3. Schematic plot of daily cycle of wind speed at Szentkirályszabadja and Jósvafő.

In the case of Szentkirályszabadja the annual minimum occurs in January, while two local maxima are found in February and July, which can be partly explained by the orography (highland location) and by the heavy convective activity in summer around the Lake Balaton.

3. Wind profile

Collaborating with AEROCARB and CHIOTTO EU-5 framework projects [9] we had the opportunity to carry out wind profile measurements near the village Hegyhátsál, at a site in the north-western part of Hungary (46.96°N, 16.65°E). Wind speed and wind direction have been observed at four levels from the end of September 1994 [10] on a 117 m tall TV and radio transmitter tower. The measuring station lies at 248 m above sea level, and is surrounded mainly by agricultural fields and forest patches. As shown in the middle part of Fig. 5, measurements are recorded at 48 m height in both a south and a north direction and at 82 and 115 m height in the north direction.

First, data set of the lowest measuring point (near surface) was analysed. This instrument is placed at 10 m above ground and 70 m away from the tower with the intention of excluding the shelter effects of the tower as much as possible. The well-known annual cycle of wind speed can be well recognised in the observed data. April is the windiest month in the Hegyhátsál area and October is the least windy month of the year, as the Hungarian wind climate can be characterised in general. Therefore, the relative wind speed frequencies of these months are presented in Fig.

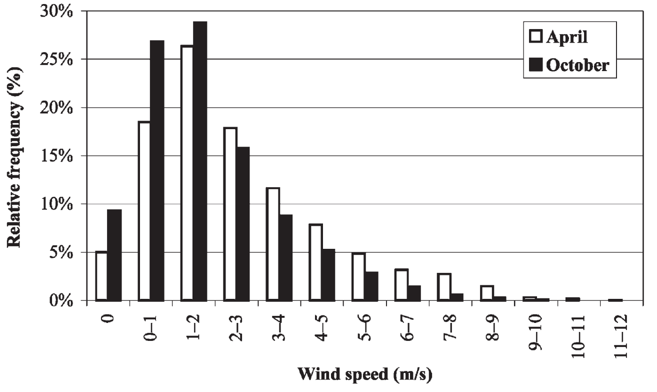


Fig. 4. Frequency distributions of wind speed for April and October at station Hegyhátsál.

4. The first columns represent the relative frequencies of wind calm periods that are relatively low compared to some other regions of Hungary. Certainly, calm periods occur much more frequently in October (9.3%) than in April (5.0%). In both months the most frequent wind speed values are in the 0–4 m s^{-1} interval. However, wind speed values above the average in April occur more often than in October.

Multilevel wind speed measuring experiments on towers are suitable to estimate the vertical profiles of wind speed. Although our data set includes errors coming from the shelter and wind field perturbation effects of the specially shaped tower, detailed profile analysis and profile fitting is able to provide appropriate information about the vertical structure of the flow. A six-year-long (1995–2000) data base measured at four levels was analyzed. Classification of wind speed values is based on the near surface time series (observed at 10 m). Periods with a wind speed less than 1 m s^{-1} were excluded from the analysis having no significant effect on wind energy production. After a detailed analysis tercile values of wind speed time series in April near the surface (2.5 m s^{-1} and 4 m s^{-1}) performed the best statistical tool to classify vertical wind profiles. Ranked data were divided into three groups with an equal number of observations. Figure 4 shows the frequency distributions of observations from the higher measuring levels (48, 82 and 115 m) based on the near surface wind speed classification described above. In order to compare the two selected months, the same threshold values (terciles of April) were used for October leading to an asymmetric distribution (46.9, 31.8 and 21.3%, respectively).

In spite of the unequal distribution of the groups of October data, relative frequencies remained smaller than in the case of April. However, large differences in wind climate cannot be observed between April and October at higher levels. As height and wind speed increase the argument of wind speed frequency function is getting larger. This may result in larger errors of wind profile estimation.

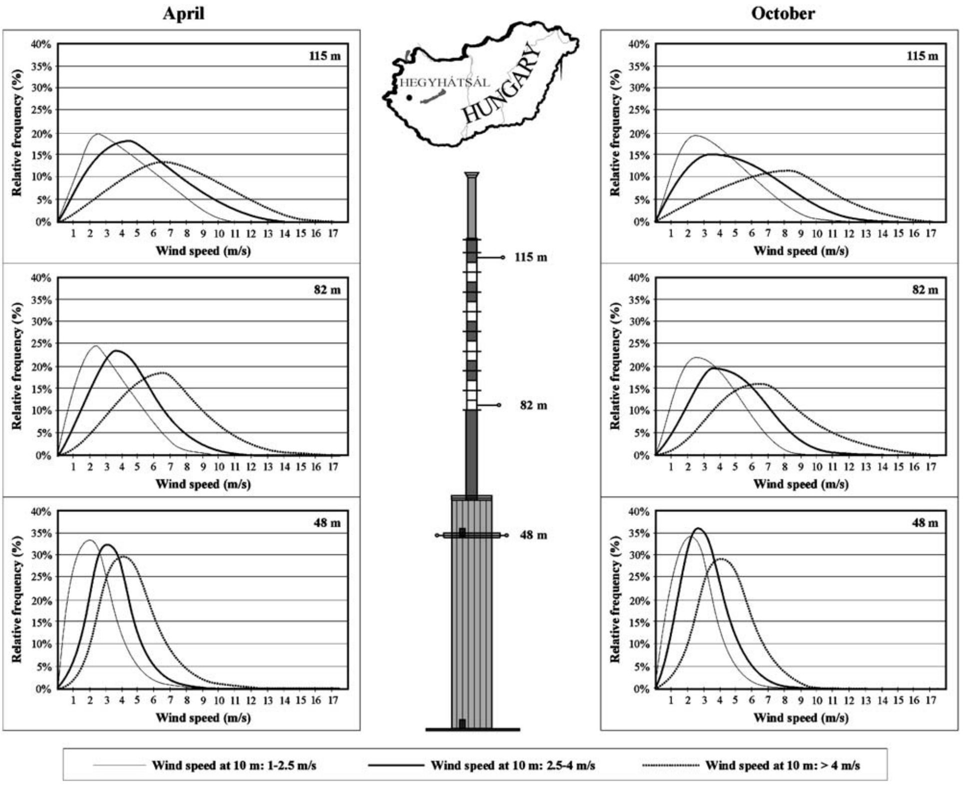


Fig. 5. Relative frequencies of wind speed observed at three levels in April and October using tercile classification of April near surface data.

4. Model estimations of wind fields

Before estimating extractable wind power or siting wind power stations, it is necessary to map the spatially continuous wind fields. Such maps can be obtained solely by using wind models. The WAsP model [11] developed at Risø National Laboratory, Roskilde, Denmark has been selected for this reason. In order to verify the WAsP model for selected regions of Hungary, input data measured at Hegyhátsál at a 10 m height have been used to model the wind field over the hilly terrain. The topography has been included in WAsP as a height-contour map using 25 m isolines. Roughness length has been set to 1.0, 0.5, and 0.1 m for forests and cities, villages and orchards, and shrublands or grasslands, respectively. In case of water bodies, 0.001 m has been chosen. Effects of every obstacle near the measuring site have been taken into consideration. We did not find considerable differences between measured and simulated values; consequently, topography of the hilly terrain does not generate remarkable model errors. Since the orography of Hungary does not show large variability in elevation above the sea level, our preliminary results suggest

that the WAsP model will provide reasonable horizontal and vertical extrapolation of all available measured wind data over this region [6].

In Fig. 6 results of a case study for the Hegyhátsál area are presented. A mean wind power field was simulated for a 40 × 40 km area around the measuring place at 60, 80, and 100 m heights. The model runs were based on the fine resolution digital terrain model (DTM 1000) and on the measured wind speed at 10 m height. The simulated mean wind speed values, as well as the topography [12] are in good agreement with the structure of the mean wind power field. Consequently, the case study demonstrates strong dependence of wind power on height and topography. In the case of carefully chosen rotor height, wind power utilisation can be promising even in the mild windy regions of Hungary.

Figure 7 demonstrates the vertical cross-sections (longitudinal and latitudinal, respectively) of available wind power fields resulting from simulations using the WAsP model. On both diagrams the vertical structure of wind power fields in the Hegyhátsál area can be recognised through the run of the 50, 100, 150, 200, and 250 W m^{-2} isolines. The isolines demonstrate the main characteristics of the topography. The decreasive isoline density with height correctly represents the vertical distribution of the wind power field. This type of estimation can provide useful tools in the case of planning and siting wind power stations.

Results of four case studies are presented in Fig. 8, where height and structure of a given wind power level (200 W m^{-2} was selected based on the results of Fig. 6) are mapped for four different sectors (60 × 60 km each) of Hungary. The right side of the figure is centered to Pápa (47.36°N, 17.49°E) and Pécs (46.01°N, 18.23°E), and the left side to Debrecen (47.49°N, 21.62°E) and Kecskemét (46.92°N, 19.75°E). The height of the selected wind power level was calculated by the WAsP model using a ten-year-long database (1991–2000) of the above mentioned measuring sites.

Considerable spatial differences are present in all sectors that can be explained partly by topography and roughness, and partly by the basic flow patterns of the region. Effects of the complex orography of the Pápa and Pécs regions result in somewhat more variable structure of isolines than the flat terrain of the Kecskemét and Debrecen regions. This type of map may support the optimal siting of wind power stations. However, the optimal solution would be to construct a map of the entire country using measurement data at many more stations and considering more detailed digital terrain models.

5. Conclusions

The sudden and widespread wind technology developments of the last decade raised the question of the effectiveness of wind energy consumption in low wind regions, such as Hungary. Main conclusions of this paper can be summarised as follows.

- The traditional coal-dominated energy structure of the country is changing slowly. In 2000, renewable energy represented only 3.6% of the total primary energy

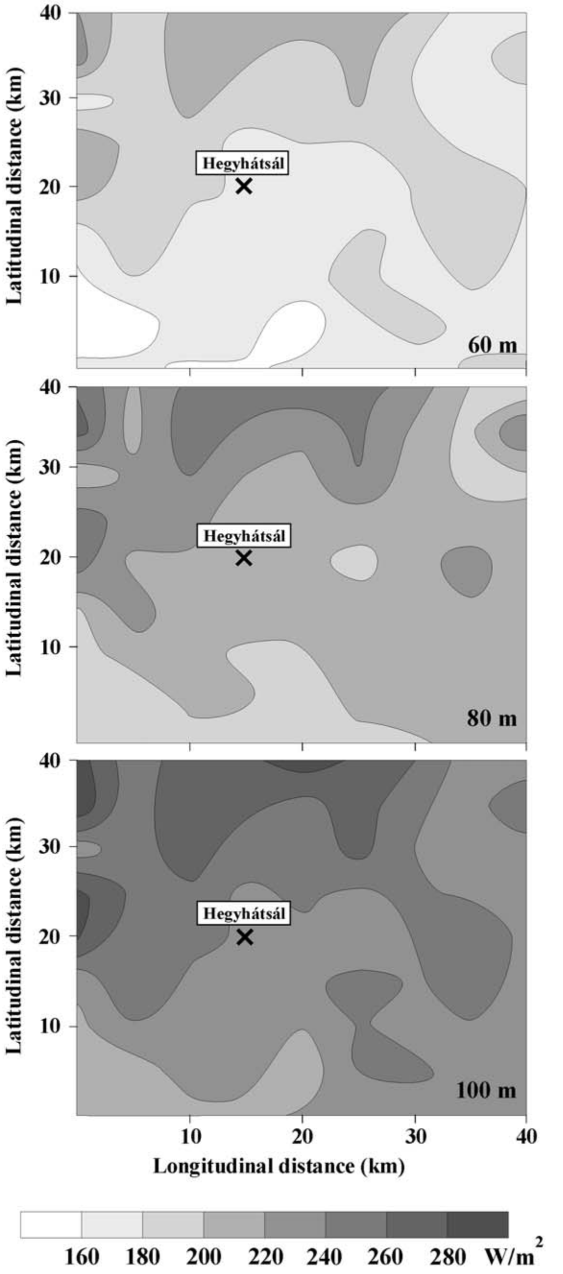


Fig. 6. Available wind power values at different levels (60, 80, 100 m) around station Hegyhátsál.

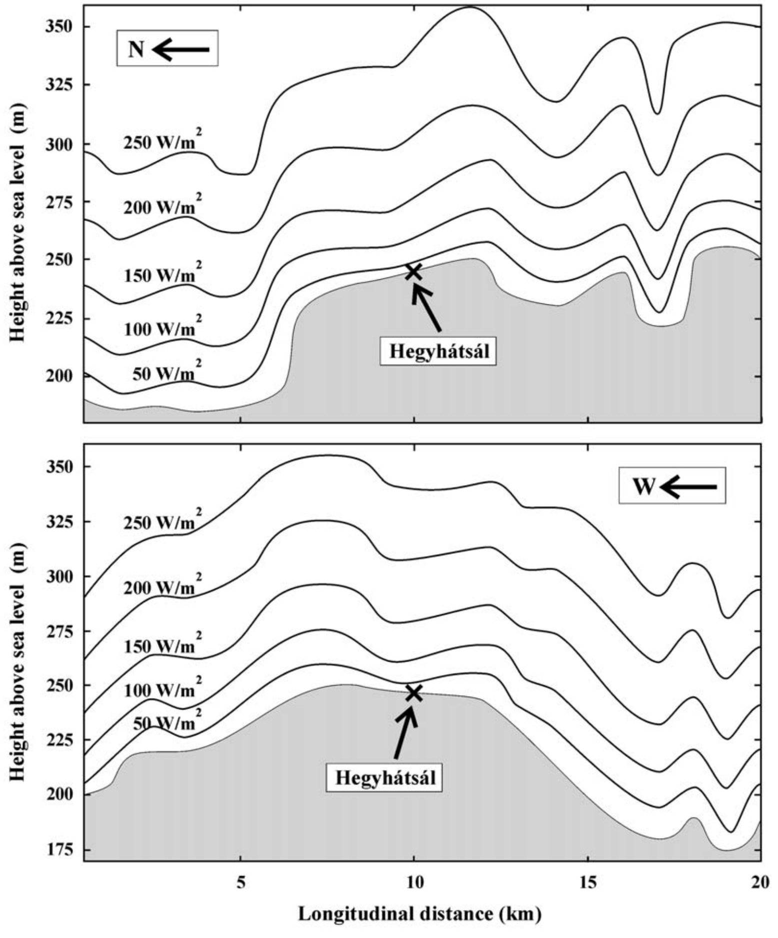


Fig. 7. Latitudinal and longitudinal vertical cross-sections of mean flow demonstrating wind power isolines around station Hegyhátsál.

consumption only, but Hungary plans to double the share of the renewable energy resources until 2010. The first wind power stations (Várpalota—250 kW and Kulcs—650 kW) were installed in 2001.

- Summarising the available wind climate information, maximum wind speed values occur in the north-western part of Hungary, while minimum centers appear in the south-western and north, north-eastern regions of the country. Generally, annual maximum and minimum values occur in the transitional seasons. However, some stations show different characteristics due to the local impacts of orography. Although annual maximum and minimum centers do not have a seasonal cycle, the analysis of transitional seasons shows that wind speed values and the range between the monthly extremes are higher in April than in October.
- Wind profile measurements and data analysis was carried out at station Hegyhát-

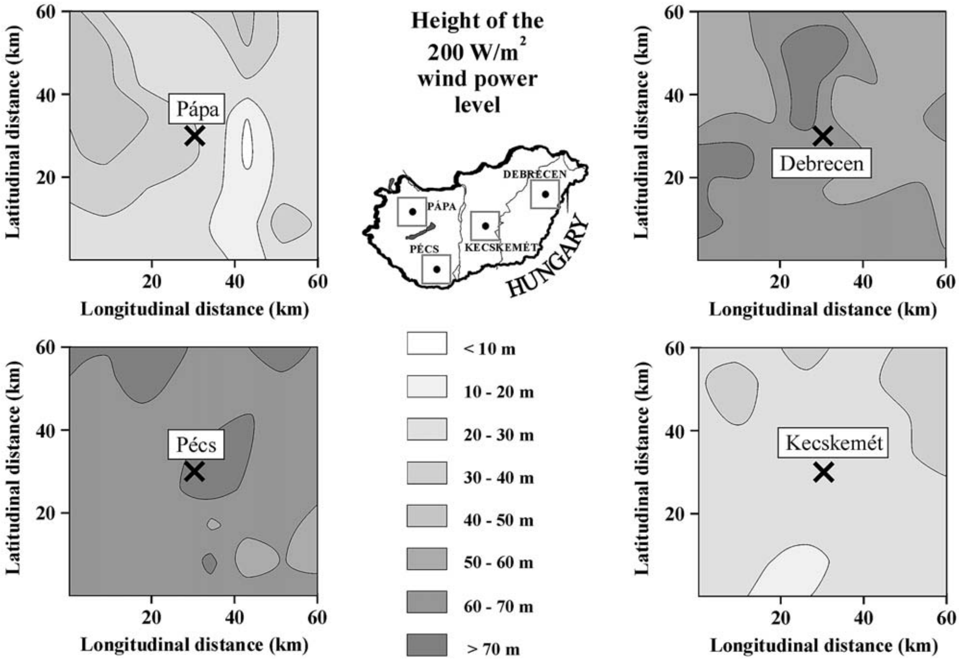


Fig. 8. The height and the structure of 200 W m^{-2} wind power level over four different sectors of Hungary.

sál, where multilevel wind speed time series are available for the 1994–2000 period. Selecting the windiest (April) and the least windy (October) months of the year, wind speed frequency distribution was analysed. Larger differences of relative frequency values observed near the surface seem to become smaller at higher levels.

- Instead of point estimations, horizontal and vertical cross-sections of available wind power fields around station Hegyhátsál are presented using the WAsP model. Three-dimensional maps provide more information, where height of the 200 W m^{-2} wind power surface is demonstrated for four different regions of Hungary. In order to have a complete overview of available wind power of the entire country further model simulations are necessary using more detailed digital terrain models and wind data from denser measuring network. In the future this type of map may support the optimal siting of wind power stations. In order to prepare the most effective renewable energy policy for the country and to make optimal decisions on planning future wind power investments it is necessary to complete the above demonstrated overview of the multilevel wind power fields of Hungary.

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